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## **Integrative research efforts at the boundary of biodiversity and global change research**

Abiven, Samuel ; Altermatt, Florian ; Backhaus, Norman ; Deplazes-Zemp, Anna ; Furrer, Reinhard ;  
Korf, Benedikt ; Niklaus, Pascal A ; Schaepman-Strub, Gabriela ; Shimizu, Kentaro K ;  
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**Abstract:** Global environmental change and biodiversity loss are closely linked through different feedback mechanisms. The University of Zurich Research Priority Programme on 'Global Change and Biodiversity' approach is to work with interdisciplinarity and transdisciplinarity to integrate mechanisms of interactions, feedback and scale and improve our understanding of the feedbacks between global change and biodiversity effects. Such work across research disciplines is not without its challenges. Here we share some of the questions that arose from our research approach over the last five years and how we addressed these challenges. First, our transdisciplinary approach allows combining different disciplines into a more holistic perspective towards integrative research, but demands collaborative work to establish common terminology, concepts, and metrics. Second, the research theme's common perspective (biodiversity is desirable, global change is not) may also induce a confirmation bias from preconceived ideas. Third, new challenges emerge from scaling mechanisms and feedbacks at different spatial and temporal scales. Fourth, we investigate how to relate biodiversity, global change, ecosystem services and functions using interdisciplinary approaches. Fifth, we identify gaps between existing experiments and data requirements, and propose the definition of new experimental setups by linking processes and performing experiments at typical experimental scales as well as at larger scales. We conclude by emphasising the necessity to integrate theory, experiments, modelling and simulation, high performance computing and big data to understand feedbacks between biodiversity loss and processes of global change.

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**Integrative research efforts at the boundary of biodiversity and global change  
research**

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24

25 **Abstract**

26 Global environmental change and biodiversity loss are closely linked through different  
27 feedback mechanisms. The University of Zurich Research Priority Programme on  
28 "Global Change and Biodiversity" approach is to work with interdisciplinarity and  
29 transdisciplinarity to integrate mechanisms of interactions, feedback and scale and  
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31 effects. Such work across research disciplines is not without its challenges. Here we share  
32 some of the questions that arose from our research approach over the last five years and  
33 how we addressed these challenges. First, our transdisciplinary approach allows  
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35 research, but demands collaborative work to establish common terminology, concepts,  
36 and metrics. Second, the research theme's common perspective (biodiversity is desirable,  
37 global change is not) may also induce a confirmation bias from preconceived ideas.  
38 Third, new challenges emerge from scaling mechanisms and feedbacks at different spatial  
39 and temporal scales. Fourth, we investigate how to relate biodiversity, global change,  
40 ecosystem services and functions using interdisciplinary approaches. Fifth, we identify  
41 gaps between existing experiments and data requirements, and propose the definition of  
42 new experimental setups by linking processes and performing experiments at typical  
43 experimental scales as well as at larger scales. We conclude by emphasising the necessity  
44 to integrate theory, experiments, modelling and simulation, high performance computing  
45 and big data to understand feedbacks between biodiversity loss and processes of global  
46 change.

47

## 48 **Introduction**

49 Biodiversity loss is one of the important processes affected by global change drivers,  
50 summarised in the Millennium Ecosystem Assessment as the 'big five': land use change,  
51 climate change, invasions, exploitation, and pollution [1]. Biodiversity loss and global  
52 change are strongly bound together through feedback mechanisms taking place at spatial  
53 and temporal scales that are usually smaller than those currently incorporated in global  
54 earth system models [2]. Each of the 'big five' has been shown to negatively impact on  
55 biodiversity [3]. However, studying these drivers independently is unlikely to provide a  
56 coherent understanding which can be used to predict how global change affects  
57 biodiversity and *vice versa*. These considerations are at the very core of the University of  
58 Zurich Research Priority Programme on "Global Change and Biodiversity" (URPP  
59 GCB). Within this programme, a multi-disciplinary group, which includes ecologists,  
60 geneticists, remote sensing, physical and human geographers, mathematicians and  
61 philosophers, collaborates to integrate mechanisms of interactions, feedback and scale to  
62 improve the understanding of the feedbacks between global change and biodiversity  
63 effects.

64 Because of this diversity of research interests, methodology and conceptual approaches,  
65 specific questions on how to address the impact of global change drivers and the  
66 feedbacks with biodiversity were discussed in our group. This led to intense  
67 transdisciplinary questioning of research directions. Here, we consider transdisciplinarity  
68 as our common effort to address scientific problems by differentiating and integrating  
69 knowledge from different scientific and societal sources [4]. Whereas including more

scientific disciplines may provide a more holistic vision, it creates new hurdles to overcome. Here, we share some of the challenges that arose from our common work over the last five years, and how we are currently working towards resolving such challenges.

#### **Terminology between disciplines**

Joint research across disciplines requires a shared vocabulary, and shared understanding of the terminology used in different disciplines. We observed when discussing terminology that consolidating the equivocacy of the vocabulary in a given discipline is often a research question in itself [5], and unifying the terminology across large overarching fields seems a major challenge. For example, the biodiversity concept can be based on species richness, however genetic composition or species traits may be included to characterize biodiversity in other interpretations within the same discipline. Others might refer to the varying perceptions and values different people have of biodiversity, for instance, as 'nature's contributions to people' [6,7]. This makes comparisons of results from studies using different terminologies very difficult, sometimes even impossible. There are efforts underway to address this challenge, such as the ongoing selection and definition of essential biodiversity variables, which will assist in harmonizing monitoring biodiversity at global scale [8]. Another approach is to develop ontologies (e.g.[9]). In our research programme we address this challenge with a series of "terminology briefs", where researchers from different disciplines work together towards a common definition of pivotal terms, such as integration, global change or phenology.

We further address such transdisciplinarity and multidisciplinary questions directly within our research programme by combining concepts such as essential biodiversity

variables, earth system processes, ecosystem services and resource frontiers within one integrative framework (fig. 1). Each of the individual projects within the URPP GCB is located within and across the concepts encouraging transdisciplinary approaches on a daily basis [10,11].

### **The positive connotation of biodiversity, the pejorative meaning of global change**

Biodiversity is mostly perceived positively and as something to be preserved and promoted. In contrast, global change is perceived negatively, a threat, which requires mitigation or adaptation to strengthen resilience, although this framing is contested in the literature [12]. This juxtaposition is well backed up in the literature and it is not our aim to question these positive or negative connotations per se. It is interesting, however, to observe that both the concepts of biodiversity and of global change may suffer from confirmation bias [13,14], i.e. the tendency to favour information in a way that confirms pre-existing predispositions towards a particular framing of these terms. Defining a more careful framing of these two ideas presents a major challenge.

Such confirmation biases have an outcome on how experiments are designed, read and analysed; the data collected, and how publications are written. Experimental designs evaluating the effect of global change tend to overestimate the amplitude of the changing drivers [15], whereas biodiversity research tends to focus on the positive effects of a larger, more diverse, number of species [14].

A major challenge is therefore to question existing connotations, to be open to all results that fulfil the standards of scientific research although they may not fit into the normative framework, and to be aware of conflicts of interest. This means taking into account the

116 connotations of the concepts of biodiversity and global change [16]. In our research  
117 program, researchers address such a challenge by, for example publishing non positive  
118 [17] or contradicting results [18], or having an in-depth ethical reflection on our research  
119 topic [19]. To challenge existing paradigms further, we need to understand our  
120 motivation for and interests in the research, such as by thinking about how we choose our  
121 research areas, subjects of study and how we formulate our research questions.

### 123 **Links to stakeholders**

124 True transdisciplinarity spans not only different research disciplines but integrates  
125 concerned stakeholders into research designs, data collection and policy transfer [20].  
126 This gives rise to the question of "governance" [10], firstly governance of the research  
127 process, and secondly governance of the process of translating research insights into  
128 policy. A global question here is "who is asking and who is addressing the question".  
129 Stakeholders are rarely consulted at the initial stage of research when scientific questions  
130 are formulated despite the major influence of such questions on the experimental design  
131 and observations [21–24]. At the same time, powerful stakeholders partially dictate  
132 which studies and infrastructures are selected and promoted for funded projects [21],  
133 giving rise to conflicts of interest as a result of political agendas. For example, the  
134 attention given to certain organisms may not reflect their importance in the ecosystems.  
135 Animal, and to a lesser extent plant, biodiversity loss is highlighted, however  
136 microbiomes are much less studied despite their major role in ecosystem functioning.

One clear challenge for future research is to evaluate what role stakeholders, policies and politics should play in the design and outcome of research and how to take this into account. Including practitioners or lay people viewpoints while developing research questions may result in very different knowledge forms (more qualitative and multidimensional but less standardized) than the results of a purely scientific approach, as shown by the involvement of beekeepers in studies about pollination [25]. Integrating the new type of data collected in citizen science [26] is a way to achieve this local and holistic overview. But caution is needed: the global picture of global change, as well as of biodiversity research, may look quite different when applied at a local scale and specific location. Transdisciplinarity research may provide more insights on how research may affect policy and practices. The link between research and conservation programs still needs to be assessed in a more holistic way [27]. Caution is required in the assessment of "efficiency of conservation", as conservation policies often fail because they are designed without taking the livelihoods of local populations into consideration and because different stakeholders have different or conflicting interests in conservation programs [10,28].

In our program, we work directly with institutions that link our research with stakeholders. We host the project office of the Future Earth global research project bioDISCOVERY [29], which manages a framework to support biodiversity and ecosystem services for policy and decision making. We lead a project to develop remotely-sensed Essential Biodiversity Variables (rs-enabled EBVs) observing and monitoring key characteristics of global biodiversity (<http://www.globdiversity.net/>) [30]. We lead an outreach project, "Biodiversity means life" (<http://biodiversitymeanslife.ch/>),



with the aim of creating an active dialogue between scientists and the general public on the topic of biodiversity.

#### **Scaling and feedbacks: from where to where?**

Scaling processes and biodiversity in space and time may be one of the most obvious challenge for biodiversity and global change research. One technical and scientific challenge is to scale up processes and feedbacks based on ecosystem functions to the level of ecosystems [31]. Research on modifications of biophysical processes induced by biodiversity change at smaller or larger scales are needed, particularly for the prediction of the dynamics in the long-term [32,33].

In our program, we propose a number of strategies to study such issues of scaling. The genetic diversity, the genetic evolution and the dynamics of model organisms, which are widespread globally, could potentially be monitored, for example *Arabidopsis* sp. or oak (*Quercus* sp.) for the plant kingdom [34,35]. Local to regional scale biodiversity scoping studies support assessment of scaling processes [36]. Investigating one model species would help our understanding of the cascade of constraints that a plant experiences in different ecosystems with their associated drivers. This would help us to disentangle the major drivers of change at different scales of study.

Another approach would be to scale up from manipulative experimental plots to landscape scales. Biodiversity-ecosystem functioning relationships have been established primarily through experimental research at the plot scale. Similar patterns found in plot experiments may be observed at landscape scale [37], although it may be less obvious to detect, because of confounding factors.

184

185 Time scales are a challenge as they add new dimensions to the above questions. It is  
186 actively studied whether the supply of genetic and epigenetic variation might not be in  
187 line with the ecological demand for adaptation as set by the rapid rate of global change  
188 [35,38]. In addition to the existing need to predict evolution over decades, changes in  
189 plant phenology triggered by global change highlights the need to scale evolutionary  
190 processes to seasons [39]. Furthermore, socio-spatial processes of resource extraction  
191 often alter landscapes within very short time scales to dramatic effects, in particular in so-  
192 called resource frontiers [40]. The interlocking of different time scales highlights the need  
193 for current predictive assumptions to be redefined: non-linearity and non-steady states  
194 should be increasingly considered when modelling across scales.

195

#### 196 **Integrating new types of data in transdisciplinary studies**

197 Following the exploration of several scales by disciplines like remote sensing,  
198 transdisciplinary projects need to integrate new types of data, providing unprecedented  
199 coverage of biodiversity indicators [41]. Such data may partly solve the spatial  
200 representativeness and abundance issues of traditional field-based assessments [42].  
201 However, remote sensing data does have limitations that need to be considered when  
202 interpreting results. For example, biodiversity and processes occurring below-ground  
203 cannot be measured directly, and the assessment of biodiversity in aquatic systems using  
204 remote sensing or other novel approaches such as eDNA [35,43], are only beginning to  
205 be fully exploited. The challenge is to reconcile biodiversity considerations at the level of  
206 an ecosystem, such as a forest, grassland or freshwater body [44], to mechanisms taking

place at a much smaller scale, such as microbial processes. The unequal access to structured data by all scientists and the heterogeneous spatial distribution of such data, make it a biased source of information to be used with caution [45]. In our program, we try to tackle this point by physically working on a given set of predefined research sites, giving us the chance to connect our data and information consistently, even by using own research practises as part of our scientific approach [46]

### **Relating species traits to ecosystem function and ecosystem services**

One overarching challenge is the link between ecosystem services, i.e. the services provided by the ecosystem to human society, and ecosystem functions, i.e. the physical, chemical and biological processes taking place in the ecosystems [47]. The temptation to associate specific functions with measured values of a given service is great, leading to a potential quantification of ecosystem services and thus to their exchangeability or even tradability that is highly problematic [48]. This may provide a means to justify conservation policies, but may also give a partial number-based evaluation of complex services like cultural ecosystem services [49]. It is also important to remember that not all concerns about biodiversity have a functional motivation or rationale, biodiversity is often also associated with intrinsic values or relational values (preferences, principles, or virtues that people associate with relationships) [50]. One way forward may be to then translate traits into functions and predict functions based on traits [51,52].

In our project, remote sensing is one of the key discipline we use to link functions and services at large scales by deriving functions from traits [36]. Increasingly, remote sensing is used to link *in-situ* observations to mechanisms and functions to ecosystem

services [41]. The association between remote sensing and genomics may lead to comprehensive phenotyping and the definition of genetically based phenomes as high-throughput sequencing of RNA (RNA-seq) provides monitoring information for diverse physiological traits such as drought stress, nutrient level and phenology [53]. Combining the spectral analysis of plant canopy reflectance and biogeochemical measurements, such as organic compounds or isotope patterns, may also contribute to linking global services and specific functions of a given ecosystem [54]. In aquatic systems, remote sensing could be used in combination with other monitoring tools such as environmental DNA to identify long-term shifts in community structure due to global change [55].

#### **Defining the next generation of experiments**

Most of the challenges described above require the acquisition of new data, structured in a different way to that which already exists: global coverage or at least global representativeness, but capturing processes at local scale, more related to traits and functions, more related to models. We need therefore to define the next generation of experiments, which can be used to extrapolate across temporal and spatial scales with increasing complexity and diversity (Fig. 2). Improved measurements may allow the collection of higher dimensional data across organisational levels, expression states, environmental conditions, and developmental timing [56].

In many parts of the different disciplines we are involved with, "proof of concept", i.e. the case study highlighting a concept, has often been preferred to research on the effect size, i.e. a more complete overview, including data contradicting the proposed theory. It

appears also that most existing experimental setups are subject to bias, such as the island effect in global change impact studies [57] or artificial ecosystem mimicking [14].

Defining new experimental setups, linking processes and large scale, biogeochemical and –physical function and remote sensing information and ground measurement, which can be directly extrapolated by models, is a new frontier in our research field. To integrate part of these aspects, Schmid et al. [58] have recently proposed guidelines for biodiversity experiments.

Along with these new sets of data we need to collect, our transdisciplinary group of researchers requires more comprehensive modelling at every level of the questions linking biodiversity and global change, from processes to ecosystem services predictions [59,60]. The transition from a modelling sand-box to nature could help to define the right type of data one needs, particularly with the aim to coordinate global change drivers and feedbacks and biodiversity evolution. Genetic evolution, phenology or trait distribution prediction in particular may help provide a new outlook on the links between global change feedbacks and biodiversity.

## **Concluding remarks**

Here we present seven challenges related to global change and biodiversity that we experienced as a group of researchers coming from as diverse disciplines as ecology, philosophy, geography and mathematics. We are trying to overcome hurdles like terminology, confirmation bias, link to stakeholders, scaling, ecosystem services cascade or new experimental setup with a series of measures, directly implemented in our

research program. Opportunity costs of working in a transdisciplinary fashion are not evident momentarily, but will pay off in the near future. Still, the key to successful transdisciplinary work involves willingness and the ability to work across disciplinary boundaries, and the capability to understand the limitations of current approaches, expanding them beyond current capabilities.

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288 **References**

- 289 1. Millennium Ecosystem Assessment: *Millenium Ecosystem assessments:*  
290 *Ecosystems and human well-being: Synthesis*. 2005.
- 291 2. Urban MC, Bocedi G, Hendry AP, Mihoub J-B, Peer G, Singer A, Bridle JR,  
292 Crozier LG, De Meester L, Godsoe W, et al.: **Improving the forecast for**  
293 **biodiversity under climate change**. *Science (80- )* 2016, **353**:aad8466-aad8466.
- 294 3. Tilman D, Clark M, Williams DR, Kimmel K, Polasky S, Packer C: **Future**  
295 **threats to biodiversity and pathways to their prevention**. *Nature* 2017, **546**:73–  
296 81.
- 297 4. Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M,  
298 Thomas CJ: **Transdisciplinary research in sustainability science: Practice,**  
299 **principles, and challenges**. *Sustain Sci* 2012, **7**:25–43.
- 300 5. Loreau M: *The Challenges of Biodiversity Science*. 2010.
- 301 6. Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R,  
302 Chan KMA, Baste IA, Brauman KA, et al.: **Assessing nature’s contributions to**  
303 **people**. *Science (80- )* 2018, **359**:270 LP-272.
- 304 7. Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Başak  
305 Dessane E, Islar M, Kelemen E, et al.: **Valuing nature’s contributions to people:**  
306 **the IPBES approach**. *Curr Opin Environ Sustain* 2017, **26–27**:7–16.
- 307 8. Pereira HM, Ferrier S, Walters M, Geller GN, Jongman RHG, Scholes RJ, Bruford  
308 MW, Brummitt N, Butchart SHM, Cardoso AC, et al.: **Essential Biodiversity**  
309 **Variables**. *Science (80- )* 2013, **339**:277–278.

- 310 9. Deans AR, Lewis SE, Huala E, Anzaldo SS, Ashburner M, Balhoff JP, Blackburn  
311 DC, Blake JA, Burleigh JG, Chanet B, et al.: **Finding Our Way through**  
312 **Phenotypes**. *PLoS Biol* 2015, **13**.
- 313 10. Holm P, Goodsite ME, Cloetingh S, Agnoletti M, Moldan B, Lang DJ, Leemans R,  
314 Moeller JO, Buendía MP, Pohl W, et al.: **Collaboration between the natural,**  
315 **social and human sciences in Global Change Research**. *Environ Sci Policy*  
316 2013, **28**:25–35.
- 317 11. Sutherland WJ, Freckleton RP, Godfray HCJ, Beissinger SR, Benton T, Cameron  
318 DD, Carmel Y, Coomes DA, Coulson T, Emmerson MC, et al.: **Identification of**  
319 **100 fundamental ecological questions**. *J Ecol* 2013, **101**:58–67.
- 320 12. Cote M, Nightingale AJ: **Resilience thinking meets social theory: Situating**  
321 **social change in socio-ecological systems (SES) research**. *Prog Hum Geogr*  
322 2012, **36**:475–489.
- 323 13. Hulme M: **Reducing the Future to Climate: A Story of Climate Determinism**  
324 **and Reductionism**. *Osiris* 2011, **26**:245–266.
- 325 14. Wardle DA: **Do experiments exploring plant diversity-ecosystem functioning**  
326 **relationships inform how biodiversity loss impacts natural ecosystems?** *J Veg*  
327 *Sci* 2016, **27**:646–653.
- 328 15. Leuzinger S, Luo Y, Beier C, Dieleman W, Vicca S, Körner C: **Do global change**  
329 **experiments overestimate impacts on terrestrial ecosystems?** *Trends Ecol Evol*  
330 2011, **26**:236–41.
- 331 16. Rudiak-Gould P: **“We Have Seen It with Our Own Eyes”: Why We Disagree**  
332 **about Climate Change Visibility**. *Weather Clim Soc* 2013, **5**:120–132.



- 333 17. Schmidt H-P, Kammann C, Niggli C, Evangelou MWH, Mackie K a., Abiven S:  
334 **Biochar and biochar-compost as soil amendments to a vineyard soil:**  
335 **Influences on plant growth, nutrient uptake, plant health and grape quality.**  
336 *Agric Ecosyst Environ* 2014, **191**:117–123.
- 337 18. Maestrini B, Nannipieri P, Abiven S: **A meta-analysis on pyrogenic organic**  
338 **matter induced priming effect.** *GCB Bioenergy* 2014, doi:10.1111/gcbb.12194.
- 339 19. Deplazes-zemp A: **Commutative Justice and Access and Benefit Sharing for**  
340 **Genetic Resources.** *Ethics, Policy Environ* 2018, **85**:1–17.
- 341 20. Bennett NJ, Roth R, Klain SC, Chan KMA, Clark DA, Cullman G, Epstein G,  
342 Nelson MP, Stedman R, Teel TL, et al.: **Mainstreaming the social sciences in**  
343 **conservation.** *Conserv Biol* 2017, **31**:56–66.
- 344 21. Schimel D, Keller M: **Big questions, big science: meeting the challenges of**  
345 **global ecology.** *Oecologia* 2015, **177**:925–34.
- 346 22. Mauser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R,  
347 Moore H: **Transdisciplinary global change research: The co-creation of**  
348 **knowledge for sustainability.** *Curr Opin Environ Sustain* 2013, **5**:420–431.
- 349 23. Darvill R, Lindo Z: **Quantifying and mapping ecosystem service use across**  
350 **stakeholder groups: Implications for conservation with priorities for cultural**  
351 **values.** *Ecosyst Serv* 2015, **13**:153–161.
- 352 24. Sténs A, Bjärstig T, Nordström EM, Sandström C, Fries C, Johansson J: **In the eye**  
353 **of the stakeholder: The challenges of governing social forest values.** *Ambio*  
354 2016, **45**:87–99.
- 355 25. Maderson S, Wynne-Jones S: **Beekeepers' knowledges and participation in**

356 **pollinator conservation policy**. *J Rural Stud* 2016, **45**:88–98.

357 26. Chandler M, See L, Copas K, Bonde AMZ, López BC, Danielsen F, Legind JK,  
358 Masinde S, Miller-Rushing AJ, Newman G, et al.: **Contribution of citizen science**  
359 **towards international biodiversity monitoring**. *Biol Conserv* 2017, **213**:280–  
360 294.

361 27. Egoh B, Rouget M, Reyers B, Knight AT, Cowling RM, van Jaarsveld AS, Welz  
362 **A: Integrating ecosystem services into conservation assessments: A review**.  
363 *Ecol Econ* 2007, **63**:714–721.

364 28. Kelly AB: **Conservation practice as primitive accumulation**. *J Peasant Stud*  
365 2011, **38**:683–701.

366 29. Krug C, Teeffelen A van, B.N. BS, Schmid B, Obura D, Metzger JP, Cavender-  
367 Bares J, Shannon L, Schaepman ME, Yasuhara M, et al.: **Observations,**  
368 **Indicators and Scenarios of Biodiversity and Ecosystem Services change – a**  
369 **framework to support policy and decision-making**. *Curr Opin Environ Sustain*  
370 2018,

371 30. Pettorelli N, Wegmann M, Skidmore A, Múcher S, Dawson TP, Fernandez M,  
372 Lucas R, Schaepman ME, Wang T, O'Connor B, et al.: **Framing the concept of**  
373 **satellite remote sensing essential biodiversity variables: challenges and future**  
374 **directions**. *Remote Sens Ecol Conserv* 2016, **2**:122–131.

375 31. Petchey OL, Pontarp M, Massie TM, Kéfi S, Ozgul A, Weilenmann M, Palamara  
376 GM, Altermatt F, Matthews B, Levine JM, et al.: **The ecological forecast**  
377 **horizon, and examples of its uses and determinants**. *Ecol Lett* 2015, **18**:597–  
378 611.

- 379 32. Zeng Z, Piao S, Li LZ, Zhou L, Ciais P, Wang T, Li Y, Lian X, Wood EF,  
380 Friedlingstein P, et al.: **Climate mitigation from vegetation biophysical**  
381 **feedbacks during the past three decades.** *Nat Clim Chang* 2017, **7**:432–436.
- 382 33. Smith NG, Dukes JS: **Plant respiration and photosynthesis in global-scale**  
383 **models: Incorporating acclimation to temperature and CO<sub>2</sub>.** *Glob Chang Biol*  
384 2013, **19**:45–63.
- 385 34. Jetz W, Cavender-Bares J, Pavlick R, Schimel D, Davis FW, Asner GP, Guralnick  
386 R, Kattge J, Latimer AM, Moorcroft P, et al.: **Monitoring plant functional**  
387 **diversity from space.** *Nat Plants* 2016, **2**:16024.
- 388 35. Yamasaki E, Altermatt F, Cavender-Bares J, Schuman MC, Zuppinger-Dingley D,  
389 Garonna I, Schneider FD, Guillén-Escribà C, van Moorsel SJ, Hahl T, et al.:  
390 **Genomics meets remote sensing in global change studies: monitoring and**  
391 **predicting phenology, evolution and biodiversity.** *Curr Opin Environ Sustain*  
392 2017, **29**:177–186.
- 393 36. Schneider FD, Morsdorf F, Schmid B, Petchey OL, Hueni A, Schimel DS,  
394 Schaepman ME: **Mapping functional diversity from remotely sensed**  
395 **morphological and physiological forest traits.** *Nat Commun* 2017, **8**:1441.
- 396 37. Oehri J, Schmid B, Schaepman-Strub G, Niklaus P: **Biodiversity promotes**  
397 **primary productivity and growing season lengthening at the landscape scale.**  
398 2017, doi:10.1073/pnas.1703928114.
- 399 38. Kokko H, Chaturvedi A, Croll D, Fischer MC, Guillaume F, Karrenberg S, Kerr B,  
400 Rolshausen G, Stapley J: **Can Evolution Supply What Ecology Demands?**  
401 *Trends Ecol Evol* 2017, **32**:187–197.

- 402 39. Garonna I, de Jong R, de Wit AJW, Mùcher C a, Schmid B, Schaepman ME:  
403 **Strong contribution of autumn phenology to changes in satellite-derived**  
404 **growing season length estimates across Europe (1982-2011).** *Glob Chang Biol*  
405 2014, doi:10.1111/gcb.12625.
- 406 40. Li TM: **What is land? Assembling a resource for global investment.** *Trans Inst*  
407 *Br Geogr* 2014, **39**:589–602.
- 408 41. Braun D, Damm A, Paul-Limoges E, Revill A, Buchmann N, Petchey OL, Hein L,  
409 Schaepman ME: **From instantaneous to continuous: Using imaging**  
410 **spectroscopy and in situ data to map two productivity-related ecosystem**  
411 **services.** *Ecol Indic* 2017, **82**:409–419.
- 412 42. Vellend M, Baeten L, Myers-Smith IH, Elmendorf SC, Beausejour R, Brown CD,  
413 De Frenne P, Verheyen K, Wipf S: **Global meta-analysis reveals no net change**  
414 **in local-scale plant biodiversity over time.** *Proc Natl Acad Sci* 2013, **110**:19456–  
415 19459.
- 416 43. Deiner K, Fronhofer EA, Mächler E, Walser J-C, Altermatt F: **Environmental**  
417 **DNA reveals that rivers are conveyer belts of biodiversity information.** *Nat*  
418 *Commun* 2016, **7**:12544.
- 419 44. Dudgeon D, Arthington AH, Gessner MO, Kawabata Z-I, Knowler DJ, Lévêque C,  
420 Naiman RJ, Prieur-Richard A-H, Soto D, Stiassny MLJ, et al.: **Freshwater**  
421 **biodiversity: importance, threats, status and conservation challenges.** *Biol Rev*  
422 2006, **81**:163.
- 423 45. Bezuidenhout LM, Leonelli S, Kelly AH, Rappert B: **Beyond the digital divide:**  
424 **Towards a situated approach to open data.** *Sci Public Policy* 2017, **44**:464–475.

- 425 46. Deplazes-Zemp A, Abiven S, Schaber P, Schaepman ME, Schaepman-Strub G,  
426 Schmid B, Shimizu K, Altermatt F: **The Nagoya Protocol could backfire on the**  
427 **Global South**. *Nat Ecol Evol* [date unknown],
- 428 47. Harrison PA, Berry PM, Simpson G, Haslett JR, Blicharska M, Bucur M, Dunford  
429 R, Egoh B, Garcia-Llorente M, Geamon N, et al.: **Linkages between biodiversity**  
430 **attributes and ecosystem services: A systematic review**. *Ecosyst Serv* 2014,  
431 9:191–203.
- 432 48. Spangenberg JH, Settele J: **Precisely incorrect? Monetising the value of**  
433 **ecosystem services**. *Ecol Complex* 2010, 7:327–337.
- 434 49. Gómez-Baggethun E, de Groot R, Lomas PL, Montes C: **The history of**  
435 **ecosystem services in economic theory and practice: From early notions to**  
436 **markets and payment schemes**. *Ecol Econ* 2010, 69:1209–1218.
- 437 50. Chan KMA, Balvanera P, Benessaiah K, Chapman M, Díaz S, Gómez-Baggethun  
438 E, Gould R, Hannahs N, Jax K, Klain S, et al.: **Opinion: Why protect nature?**  
439 **Rethinking values and the environment**. *Proc Natl Acad Sci* 2016, 113:1462–  
440 1465.
- 441 51. Laureto LMO, Cianciaruso MV, Samia DSM: **Functional diversity: An overview**  
442 **of its history and applicability**. *Nat e Conserv* 2015, 13:112–116.
- 443 52. Schweiger AK, Schütz M, Risch AC, Kneubühler M, Haller R, Schaepman ME:  
444 **How to predict plant functional types using imaging spectroscopy: linking**  
445 **vegetation community traits, plant functional types and spectral response**.  
446 *Methods Ecol Evol* 2017, 8:86–95.
- 447 53. Cavender-Bares J, Meireles JE, Couture JJ, Kaproth MA, Kingdon CC, Singh A,

- Serbin SP, Center A, Zuniga E, Pilz G, et al.: **Associations of leaf spectra with genetic and phylogenetic variation in oaks: Prospects for remote detection of biodiversity.** *Remote Sens* 2016, **8**.
54. Cavender-bares J, Polasky S, King E, Balvanera P: **A sustainability framework for assessing trade-offs in ecosystem services.** 2015, **20**.
55. Jackson MC, Weyl OLF, Altermatt F, Durance I, Friberg N, Dumbrell AJ, Piggott JJ, Tiegs SD, Tockner K, Krug CB, et al.: **Recommendations for the Next Generation of Global Freshwater Biological Monitoring Tools.** *Adv Ecol Res* 2016, **55**:615–636.
56. Dhondt S, Wuyts N, Inzé D: **Cell to whole-plant phenotyping: The best is yet to come.** *Trends Plant Sci* 2013, **18**:1360–1385.
57. Leuzinger S, Fatichi S, Cusens J, Körner C, Niklaus PA: **The “island effect” in terrestrial global change experiments: a problem with no solution?** *AoB Plants* 2015, **7**:plv092.
58. Schmid B, Baruffol M, Wang Z, Niklaus PA: **A guide to analyzing biodiversity experiments.** *J Plant Ecol* 2017, **10**:91–110.
59. Nelson E, Mendoza G, Regetz J, Polasky S, Tallis H, Cameron DR, Chan KMA, Daily GC, Goldstein J, Kareiva PM, et al.: **Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales.** *Front Ecol Environ* 2009, **7**:4–11.
60. Thuiller W, Albert C, Araújo MB, Berry PM, Cabeza M, Guisan A, Hickler T, Midgley GF, Paterson J, Schurr FM, et al.: **Predicting global change impacts on plant species’ distributions: Future challenges.** *Perspect Plant Ecol Evol Syst*

2008, 9:137–152.

## Featured articles

\* Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamon, N., Geertsema, W., Lommelen, E., Meiresonne, L., Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services* 9, 191–203. doi:10.1016/j.ecoser.2014.05.006

This literature review links biodiversity characteristics and traits to a selection of ecosystem services. It shows several positive relationships, but also the complexity of the interactions between the biodiversity and the service provision.

\* Chan, K.M.A., Balvanera, P., Benessaiah, K., Chapman, M. & Díaz, S., 2016. Why protect nature? Rethinking values and the environment. *PNAS*, 113(6), pp.1462–1465.

This opinion paper is linking environmental policy, nature protection and values associated to nature. It is reframing the discussion about instrumental and relational values.

\* Chandler, M., See, L., Copas, K., Schmidt, A., Claramunt, B., Danielsen, F., Legrind, J., Masinde, S., Miller Rushing, A.; Newman, G., et al., 2016. Contribution of citizen science towards international biodiversity monitoring. *Biological*

494 Conservation. doi:10.1016/j.biocon.2016.09.004

495 This article shows the use of citizen science to assess the essential biodiversity variables.

496 It explores what can be learnt from successful experiences.

497 \*\* Pereira, H.M., Ferrier, S., Walters, M., Geller, G.N., Jongman, R.H.G., Scholes, R.J.,

498 Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C.,

499 Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz,

500 W., Karp, D.S., McGeoch, M.A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B.,

501 Sayre, R., Scharlemann, J.P.W., Stuart, S.N., Turak, E., Walpole, M., Wegmann, M.,

502 2013. Essential Biodiversity Variables. Science 339, 277–278.

503 doi:10.1126/science.1229931

504 This article describes the basis of a harmonized monitoring of biodiversity at global scale.

505 It defines the theoretical background of such effort, but put it also into practice.

506 \*\* Wardle, D.A., 2016. Do experiments exploring plant diversity-ecosystem functioning

507 relationships inform how biodiversity loss impacts natural ecosystems? Journal of

508 Vegetation Science 27, 646–653. doi:10.1111/jvs.12399

509 This article questions point by point the validity of the biodiversity experiments as

510 developed until now. It addresses specifically the question about the analogy between

511 these experiments and the “real” ecosystems.